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International Telecommunication Union
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Recommendation

ITU-T Y.3550 (12/2023)

SERIES Y: Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

Cloud Computing

Cloud computing – Requirements for artificial intelligence based cloud service development and operation management

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Recommendation ITU-T Y.3550

Cloud computing – Requirements for artificial intelligence based cloud service development and operation management

Summary

Recommendation ITU-T Y.3550 aims to provide an overview of artificial intelligence (AI) based cloud service development and operation management based on Recommendation ITU-T Y.3525. It impacts four lifecycle stages of cloud service development and operation management with AI capabilities to improve software development and operation management efficiency. Additionally, this Recommendation also specifies the functional requirements of AI based cloud service development and operation management derived from the corresponding use cases.

History*

Edition	Recommendation	Approval	Study Group	Unique ID
1.0	ITU-T Y.3550	2023-12-14	13	11.1002/1000/15747

Keywords

Artificial intelligence, cloud service, development and operation, operation management.

* To access the Recommendation, type the URL https://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID.

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Cloud computing – Requirements for artificial intelligence based cloud service development and operation management

1 Scope

This Recommendation provides functional requirements and typical use cases of artificial intelligence (AI) based cloud service development and operation management. The scope of this Recommendation includes the following aspects.

– Overview of AI based cloud service development and operation management;

– Functional requirements of AI based cloud service development and operation management;

– Typical use cases of AI based cloud service development and operation management.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T X.1601] Recommendation ITU-T X.1601 (2015), *Security framework for cloud computing*.

[ITU-T Y.3525] Recommendation ITU-T Y.3525 (2020), *Requirements for cloud service development and operation management*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 artificial intelligence [b-ISO/IEC 2382]: An interdisciplinary field, usually regarded as a branch of computer science, dealing with models and systems for the performance of functions generally associated with human intelligence, such as reasoning and learning.

3.1.2 cloud computing [b-ITU-T Y.3500]: Paradigm for enabling network access to a scalable and elastic pool of shareable physical or virtual resources with self-service provisioning and administration on demand.

NOTE – Examples of resources include servers, operating systems, networks, software, applications, and storage equipment.

3.1.3 cloud service [b-ITU-T Y.3500]: One or more capabilities offered via cloud computing invoked using a defined interface.

3.1.4 cloud service customer [b-ITU-T Y.3500]: Party which is in a business relationship for the purpose of using cloud services.

3.1.5 cloud service partner [b-ITU-T Y.3500]: Party which is engaged in support of, or auxiliary to, activities of either the cloud service provider or the cloud service customer, or both.

3.1.6 cloud service provider [b-ITU-T Y.3500]: Party which makes cloud services available.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AI Artificial Intelligence

CSC Cloud Service Customer

CSN Cloud Service Partner

CSP Cloud Service Provider

IDE Integrated Development Environment

NLP Natural Language Processing

5 Conventions

In this Recommendation:

The keywords "**is required**" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this Recommendation is to be claimed.

The keywords "**is recommended**" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

In the body of this Recommendation and its annexes, the words shall, shall not, should, and may sometimes appear, in which case they are to be interpreted, respectively, as is required to, is prohibited from, is recommended, and can optionally. The appearance of such phrases or keywords in an appendix or in material explicitly marked as informative is to be interpreted as having no normative intent.

6 Overview of AI based cloud service development and operation management

Based on the consideration of labour cost and R&D efficiency, traditional development and operation methods are not suitable for increasing the complexity of software development and operation. The way of development and operation is changing from manual to intelligence.

AI based cloud service development and operation management refers to applying AI algorithms and models to development and operation in a cloud computing environment in order to make decisions and analysis by using the operation and maintenance data, such as intelligent code completion and code review, automated test case generation, root cause analysis and fault diagnosis, fault prediction, and resource capacity prediction which greatly improves the development and operation efficiency for cloud service partner (CSP).

6.1 Introduction to AI based cloud service development and operation management

Based on the development and operation stage specified in [ITU-T Y.3525], CSN provides intelligent methods to analyse data and establish intelligent models to improve software development and operation management efficiency, which supports CSP to generate codes and test cases, and find problems from the massive operational data. Meanwhile, CSP measures and analyses feedback from cloud service customer (CSC) and provides updated or new implementation for the development stage defined in [ITU-T Y.3525].

6.2 AI based cloud service development and operation management framework

The AI-based cloud service development and operation management framework, shown in Figure 6-1, introduces AI-based algorithms and models based on [ITU-T Y.3525], particularly impacting four lifecycle stages, including the code stage, test stage, deploy and release stage, and the operation stage. With AI capabilities, it further assists CSN and CSP in improving development and operation efficiency from complex software development and operation.

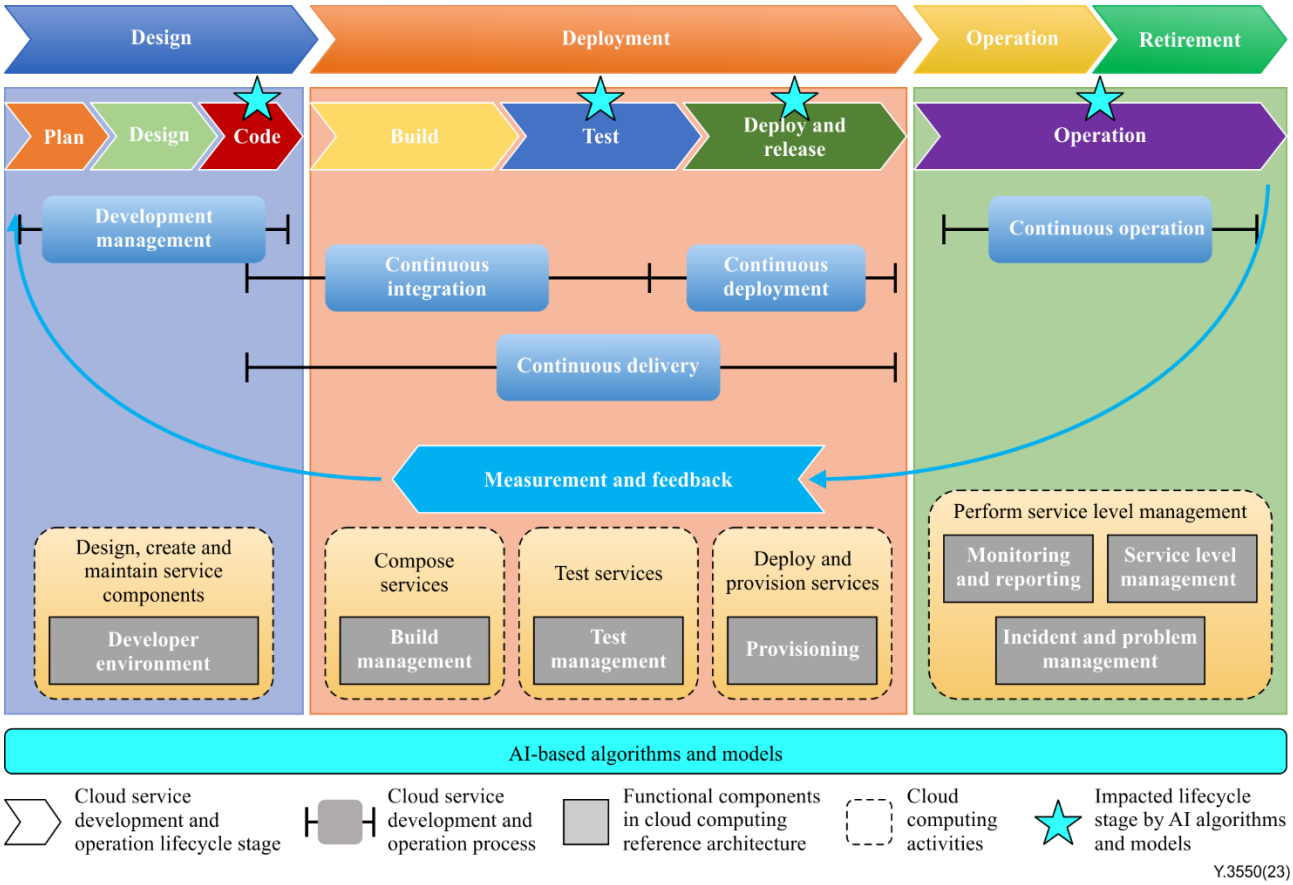


Figure 6-1 – AI based cloud service development and operation management framework

6.2.1 AI-based algorithms and models

AI-based algorithms and models provide the underlying algorithm capability support, which covers the basic algorithm library, model building, model management, and so on. CSN analyses and visualizes the operational data according to AI-based algorithms and models to enhance the lifecycle stages including the code stage, test stage, deploy and release stage, and operation stage.

6.2.2 AI-based code stage

At this stage, AI-based algorithms and models enhance the code stage of the cloud service development and operation management specified in [ITU-T Y.3525]. CSN triggers the automatic generation of codes based on AI-based algorithms and models.

6.2.3 AI-based test stage

At this stage, AI-based algorithms and models enhance the test stage of the cloud service development and operation management specified in [ITU-T Y.3525]. CSN triggers the automatic generation of test cases based on AI-based algorithms and models, in order to improve test case coverage.

6.2.4 AI-based deploy and release stage

At this stage, AI-based algorithms and models enhance the deploy and release stage of the cloud service development and operation management specified in [ITU-T Y.3525]. CSN triggers the automated process of code construction and deployment into the production environment as a cloud service based on AI-based algorithms and models, and then CSP releases it to the CSC.

6.2.5 AI-based operation stage

At this stage, AI-based algorithms and models enhance the operation stage of the cloud service development and operation management specified in [ITU-T Y.3525]. CSP monitors the events and changes, accurately identifies the root cause, automatically triggers the repair process, optimizes the usage of resources and continuously collects repair behaviours for the reduction of response system errors of the cloud service based on AI-based algorithms, so as to improve the operation and maintenance efficiency and ensure its continuity and better CSC's service experience.

7 Functional requirements of AI based cloud service development and operation management

7.1 Overview

This clause provides the derived functional requirements of AI based cloud service development and operation management based on the use cases in Appendix I. The functional requirements could be mapped with four stages as follows.

– Functional requirement for AI-based code stage: code generation (7.2).

– Functional requirement for AI-based test stage: test case generation (7.3).

– Functional requirement for AI-based deploy and release stage: integration and deployment (7.4).

– Functional requirement for AI-based operation stage: abnormal detection (7.5), alarm convergence (7.6), fault localization (7.7), fault repairing (7.8), resource optimization (7.9), resource capacity prediction (7.10), intelligent response (7.11) and knowledge base management (7.12).

7.2 Code generation

It is required that CSN supports the AI based code completion options as integrated development environment (IDE) tools according to the code fragments entered by CSP and the programming language syntax rules.

NOTE – One of the AI based code completion is sorting to improve the effectiveness of code usage for code fragment recommendation.

7.3 Test case generation

It is recommended that the CSN supports the automatic generation of test cases by AI algorithms and models.

NOTE – Natural language processing is one option for creating test cases.

It is recommended that CSN supports intelligent optimization of test cases based on the historical testing data and results.

It is recommended that CSN supports adaptive adjustment of test cases based on changes in the testing environment of the CSP.

7.4 Integration and deployment

It is required that CSN supports intelligent diagnosis and error correction on code changes by AI algorithms and models analysis.

7.5 Abnormal detection

It is required that CSP completes anomaly detection by using an AI algorithm to improve detection accuracy.

NOTE 1 – Single-index based anomaly detection should be supported by CSN.

NOTE 2 – Anomaly detection algorithm model includes 3-sigma model, LR model, etc.

It is recommended that CSN supports adaptive model anomaly detection for different cloud service indicators.

NOTE 3 – Cloud service indicators include resource usage, access success rate, response time, etc.

It is recommended that CSN supports optimized models through continuous updates of anomaly detection AI models.

7.6 Alarm convergence

It is recommended that CSN supports automatic convergence based on AI algorithms and models to compress the same or similar alarms.

It is recommended that CSN supports intelligently completing alarm convergence from different dimensions based on the algorithms.

NOTE – The alarm convergence mechanism selects one or more appropriate dimensions to merge the alarm messages. Dimensions include but are not limited to server, cluster, network segment, etc.

It is recommended that CSN supports self-learning of the alarm convergence.

7.7 Fault localization

It is required that CSP uses different AI algorithms to analyse operational data and find the root cause of system faults.

NOTE 1 – Data types include but are not limited to metrics and logs.

It is recommended that CSN supports the display of latent fault propagation relationship and the faults update.

NOTE 2 – Latent fault propagation relationship includes but is not limited to correlation and causality between different faults.

7.8 Fault repairing

It is recommended that CSN supports automatic fault recovery.

It is recommended that CSN supports automatic fault repair recommendation solutions based on the AI algorithms and models to analyse historical operational data.

7.9 Resource optimization

It is recommended that CSN provides AI models to predict resource usage and recommends resource optimization.

NOTE 1 – Resource optimization includes but is not limited to capacity expansion, capacity reduction, balanced allocation, optimized configuration, etc.

NOTE 2 – Resource optimization recommendation is achieved by processing cloud service capacity usage data.

7.10 Resource capacity prediction

It is recommended that CSN provides a prediction of resource capacity by AI algorithms and models.

NOTE – Prediction model could be constructed based on a single indicator of time series data.

It is recommended that CSN supports AI algorithms and models to predict resource capacity in different time periods, such as short-term resource capacity prediction and long-term resource capacity prediction.

It is recommended that CSN supports the visualization of capacity prediction and early warning.

7.11 Intelligent response

It is recommended that CSP uses semantic analysis for the relevance of CSC's requests based on the knowledge base and other historical operational data.

It is recommended that CSN supports model training by labelling CSC's feedback data in order to automatically proofread and improve responses.

It is recommended that CSN supports multiple response types.

NOTE – The response types include but are not limited to single-round conversation, multi-round conversation, one question and multiple answers, etc.

7.12 Knowledge base management

It is recommended that CSN supports automatically obtaining knowledge information from multiple data sources, and updating knowledge base.

NOTE – The knowledge base could support AI based model generation and optimization.

It is recommended that CSN supports knowledge association analysis and provides the recommended results to the CSP.

It is recommended that CSN supports knowledge content tags and classifications, automatic merge and updates based on knowledge similarity.

8 Security considerations

Security aspects for consideration within the cloud computing environment, which are addressed by security challenges for CSPs and CSNs, are described in [ITU-T X.1601]. [ITU-T X.1601] analyses security threats and challenges, and describes security capabilities that could mitigate these threats and satisfy the security challenges.

Appendix I

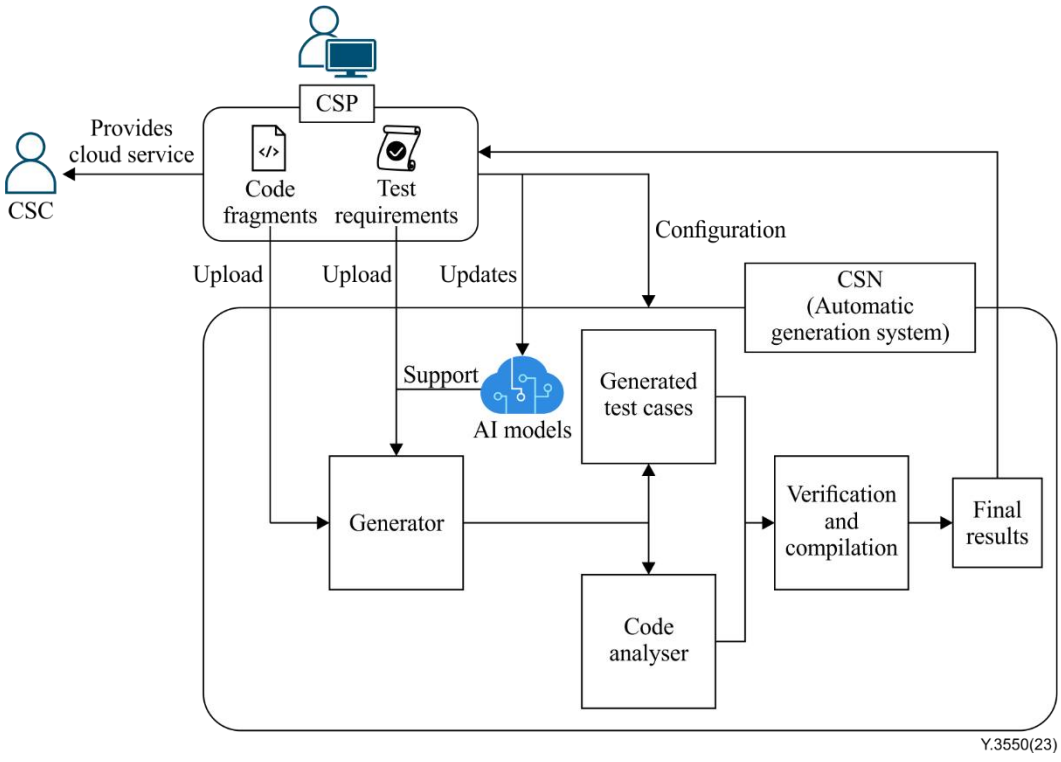
Use case of AI based operation management

(This appendix does not form an integral part of this Recommendation.)

This appendix includes the AI based operation management related use cases based on which the corresponding functional requirements are derived.

I.1 Use case: automatic generation of codes and test cases

Table I.1 – Use case: automatic generation of codes and test case

Title	Automatic generation of codes and test cases
Description	CSN provides the automatic generation system, which supports the automatic code completion and automatic generation of test cases through AI models configured by CSP. 1) CSP configures the parameters of the automatic generation system and uploads code fragments or test requirements lists in it. 2) CSP updates generated codes and test cases in the AI model repository for further training. 3) CSP provides cloud service to CSC based on an automatic generation system.
Roles	CSN, CSP, CSC
Figure (optional)	 **Figure I.1 – Automatic generation of codes and test cases**
Pre-conditions (optional)	
Post-conditions (optional)	
Derived requirements	– code generation (refer to clause 7.2) – test case generation (refer to clause 7.3)

I.2 Use case: integration and deployment

Table I.2 – Use case: integration and deployment

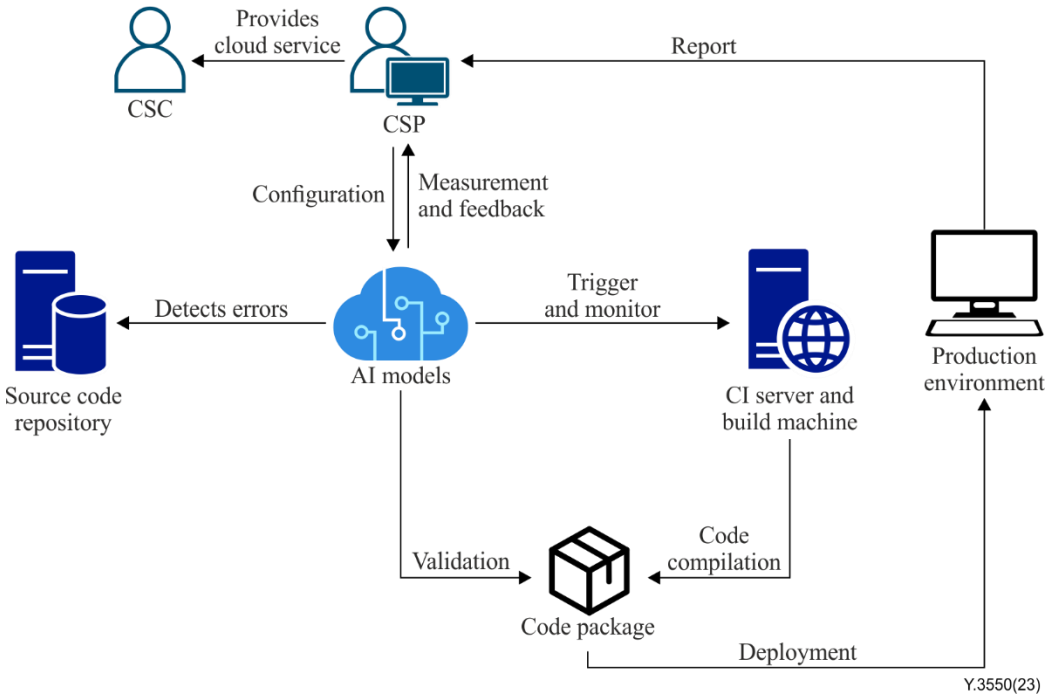
Title	Integration and deployment
Description	The automated code integration and configuration are triggered by the CSP. The submitted source codes are automatically compiled and deployed after the AI model validation. 1) CSP configures the parameters of AI models to automatically detect errors when source codes change and then triggers a continuous integration server to compile codes. 2) CSP configures the parameters of AI models to automatically build code package and deploys it to the production environment. 3) CSP updates the AI model and provides cloud service to CSC.
Roles	CSP, CSC
Figure (optional)	
Pre-conditions (optional)	
Post-conditions (optional)	
Derived requirements	– integration and deployment (refer to clause 7.4)

Figure I.2 – Integration and deployment

I.3 Use case: adaptive anomaly detection model adjustment

Table I.3 – Use case: adaptive anomaly detection model adjustment

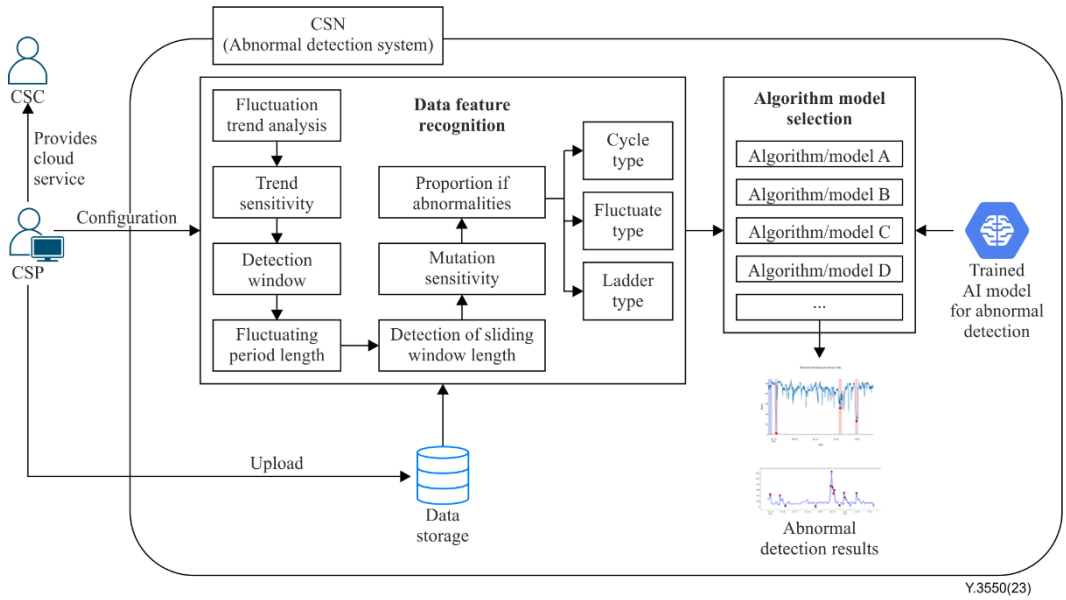
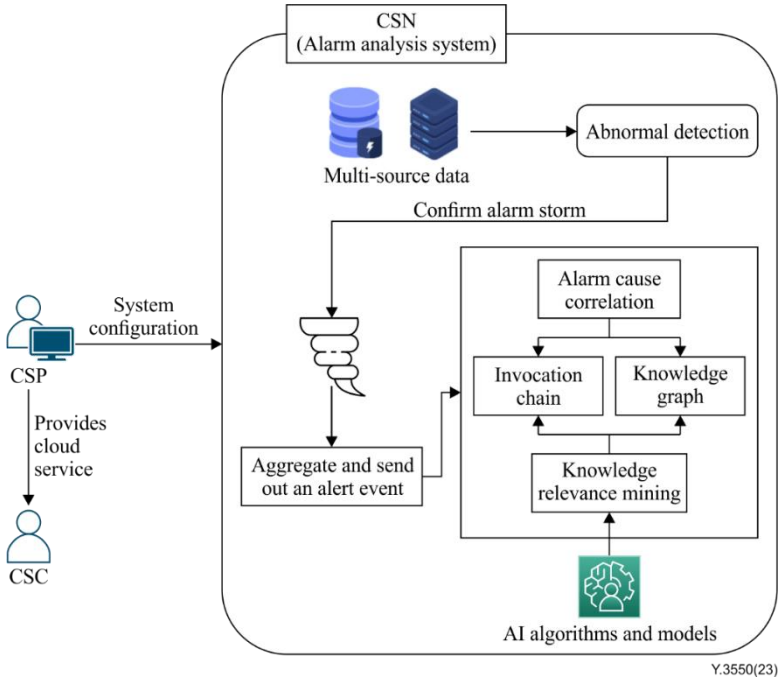
Title	Adaptive anomaly detection model adjustment
Description	CSN provides the anomaly detection system in a production environment, in which the characteristics of the CSP's operational data are recognized by the adaptively matched algorithms. For example, CSN provides four different algorithms (algorithms A, B, C and D). Algorithms A and B are used to detect the data characteristics as ladder type, and algorithms C and D are used to detect the data characteristics as fluctuate type, etc. When the data characteristics change from ladder type to fluctuate type, the system will match the adaptive algorithm for anomaly detection. 1) CSP configures the parameters of data feature recognition and uploads the operational data in the anomaly detection system. 2) The configuration steps in the data feature recognition mechanism as follows are performed to identify the characteristics of the CSP's operational data. a) Fluctuation trend analysis. b) Trend sensitivity configuration. c) Detection window configuration. d) Fluctuating period length configuration. e) Detection of sliding window length. f) Mutation sensitivity configuration. g) Abnormalities proportion calculation. 3) The data characteristics are classified into three different types: cycle, ladder, and fluctuate. 4) Different types of algorithm models are selected automatically for anomaly detection in the algorithm model selection mechanism. 5) CSP provides cloud service to CSC based on an anomaly detection system.
Roles	CSN, CSP, CSC
Figure (optional)	 **Figure I.3 – Adaptive anomaly detection model adjustment**
Pre-conditions (optional)	
Post-conditions (optional)	

Table I.3 – Use case: adaptive anomaly detection model adjustment

Derived requirements	– abnormal detection (refer to clause 7.5)

I.4 Use case: convergence of alarm storms

Table I.4 – Use case: convergence of alarm storms

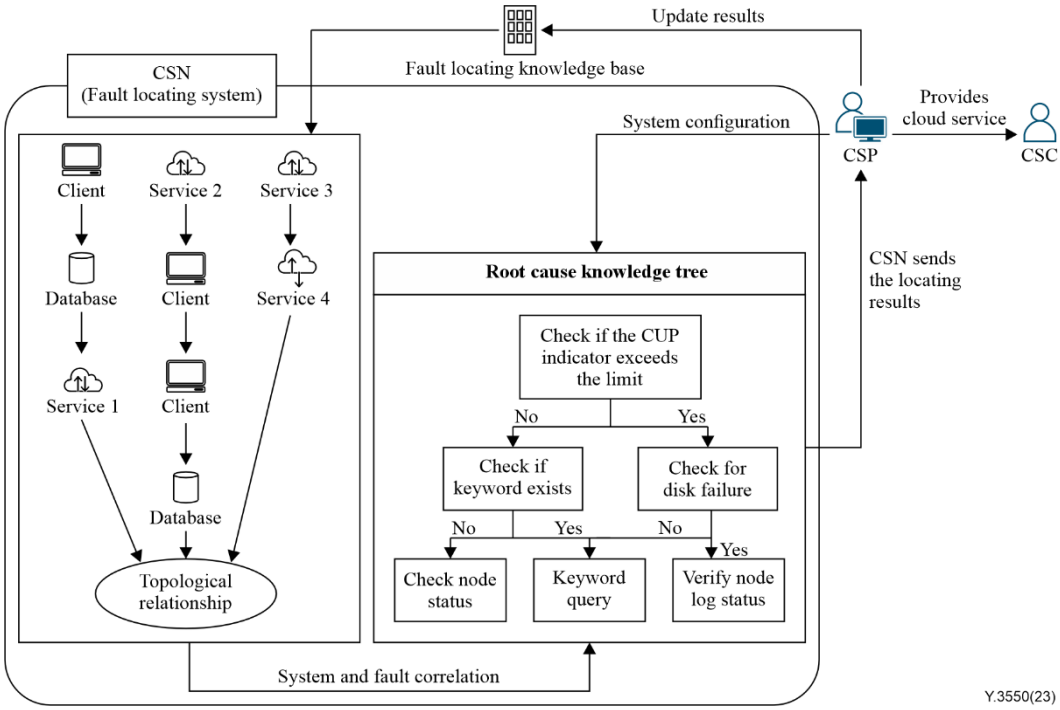
Title	Convergence of alarm storms
Description	CSN provides CSP with the alarm analysis system to aggregate the same types of alarm information in order to help CSP find problems from a large amount of short-term alarm information, locate the problem and provide fault repair solutions. The alarm analysis system provides AI algorithms and models for knowledge association through alarm storm identification and alarm cause analysis.
Roles	CSN, CSP, CSC
Figure (optional)	 **Figure I.4 – Convergence of alarm storms**
Pre-conditions (optional)	
Post-conditions (optional)	
Derived requirements	– alarm convergence (refer to clause 7.6)

I.5 Use case: fault localization based on link topology

Table I.5 – Use case: fault localization based on link topology

Title	Fault localization based on link topology
Description	The fault root cause localization system is provided by CSN based on the topological relationship of different inter-connected systems. When the cloud service indicator sounds the alarms, the fault root cause is located based on a complete topological

Table I.5 – Use case: fault localization based on link topology

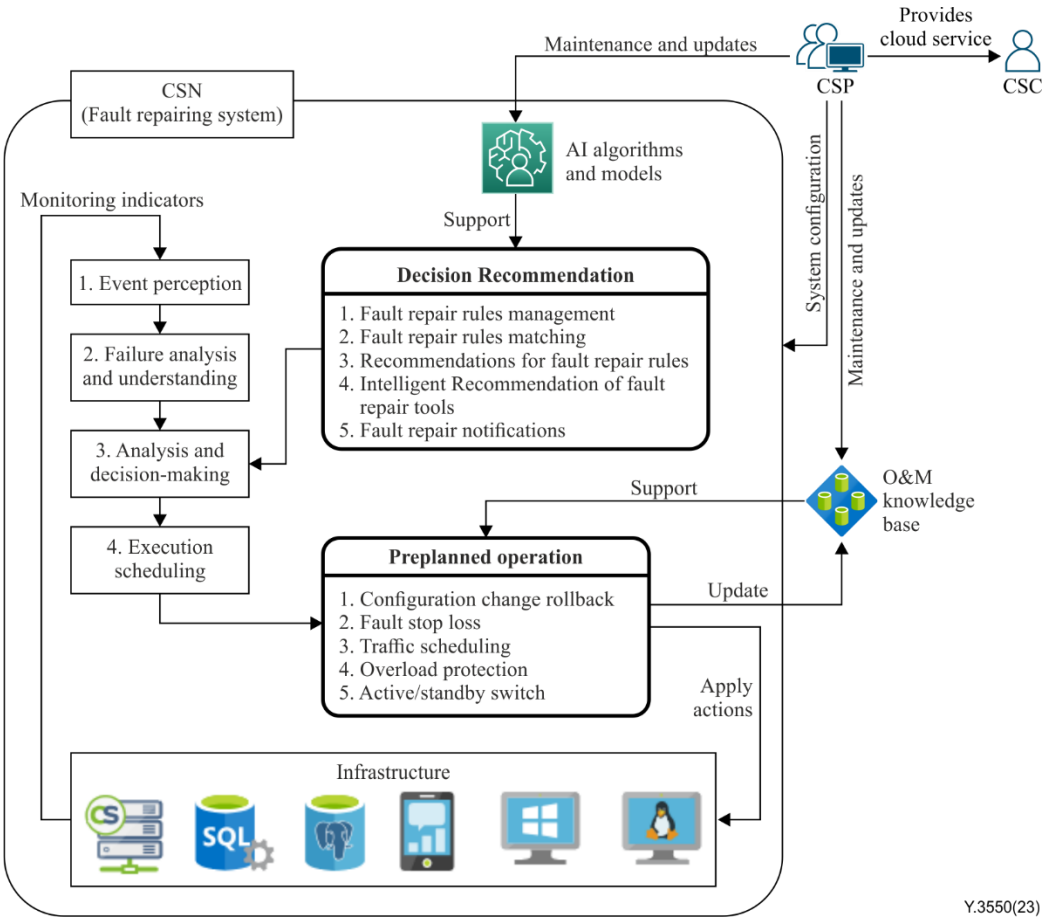
	structure for multiple systems and the localization algorithm. CSP configures the parameters of the fault root cause localization algorithm and updates the fault localization knowledge base based on the results of the fault localization. Some of these parameters are used for generating the fault root cause tree, which supports finding the fault root cause in the different inter-connected systems.
Roles	CSN, CSP, CSC
Figure (optional)	 **Figure I.5 – Fault localization based on link topology**
Pre-conditions (optional)	CSP collects topology information of different inter-connected systems. CSP maintains the fault localization knowledge base.
Post-conditions (optional)	
Derived requirements	– fault localization (refer to clause 7.7)

I.6 Use case: fault repairing solution recommendation

Table I.6 – Use case: fault repairing solution recommendation

Title	Fault repairing solution recommendation
Description	CSN provides CSP with a fault repairing system based on AI algorithms and models to support continuous updated fault repair solution suggestions. CSP configures the parameters of the fault repairing system in the execution scheduling phase of fault repairing pre-processing based on the relevant operation and maintenance knowledge base.
Roles	CSN, CSP, CSC

Table I.6 – Use case: fault repairing solution recommendation

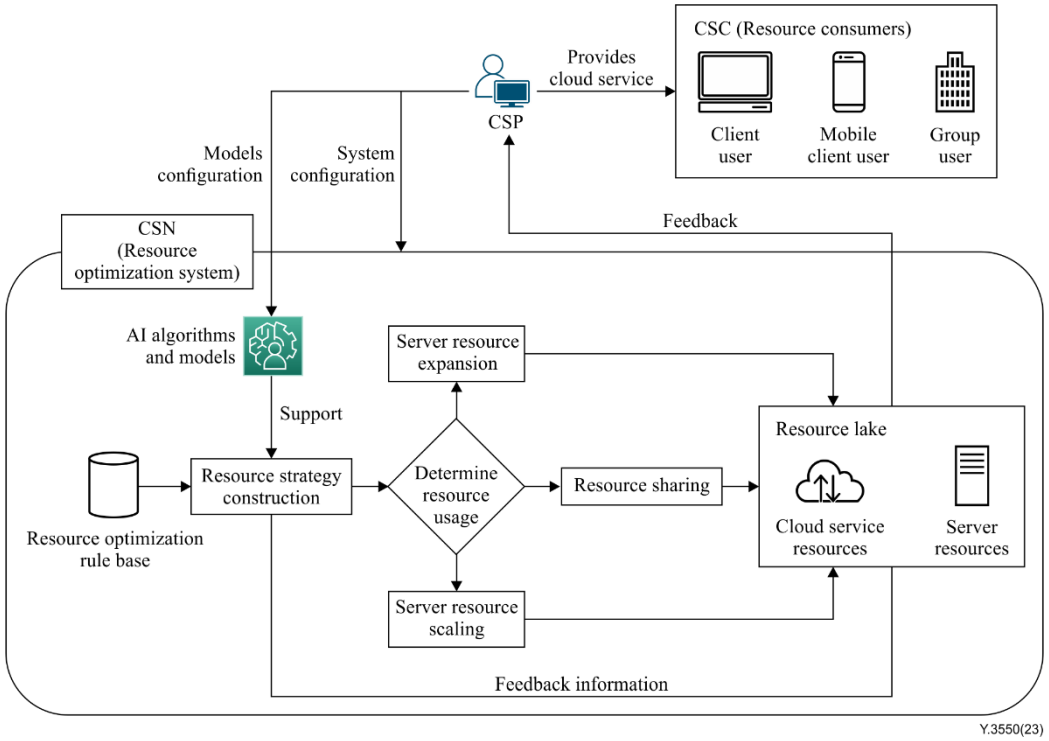
Figure (optional)	 **Figure I.6 – Fault repairing solution recommendation**
Pre-conditions (optional)	CSP provides infrastructure monitoring tools or system.
Post-conditions (optional)	
Derived requirements	– fault repairing (refer to clause 7.8)

I.7 Use case: resource optimization and scheduling

Table I.7 – Use case: resource optimization and scheduling

Title	Resource optimization and scheduling
Description	CSN provides the resource optimization and scheduling system based on AI algorithms and models. The models could adjust the resource allocation policy by analysing the current resource usage and future resource usage trends, including resource capacity expansion and reduction. CSP configures the parameters of the resource optimization and scheduling system and schedules the resource based on the optimization solution provided by this system.
Roles	CSN, CSP, CSC

Table I.7 – Use case: resource optimization and scheduling

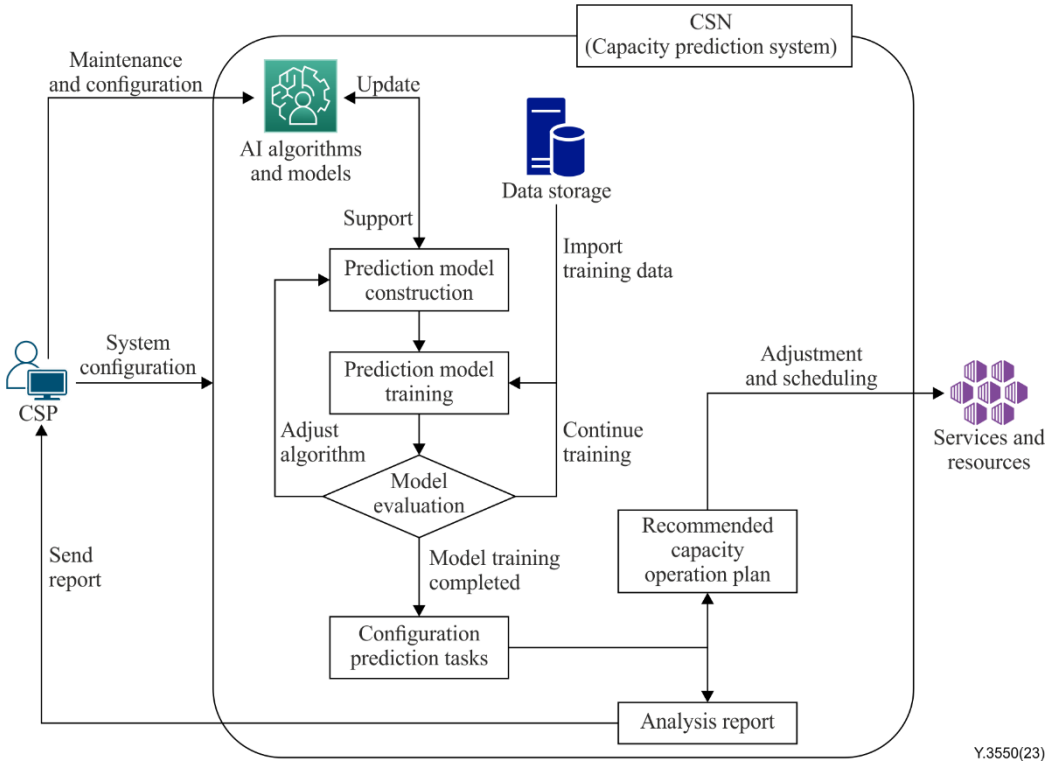
Figure (optional)	 **Figure I.7 – Resource optimization and scheduling**
Pre-conditions (optional)	CSP collects resource usage data.
Post-conditions (optional)	
Derived requirements	– resource optimization (refer to clause 7.9)

I.8 Use case: resource capacity prediction

Table I.8 – Use case: resource capacity prediction

Title	Resource capacity prediction
Description	CSN provides a capacity prediction system, including mechanisms such as prediction model construction, prediction model training, prediction model evaluation and capacity operation plan recommendation, for analysing the historical operational data of service and resource performance based on AI algorithms and models, and automatically planning and managing resource usage to achieve capacity prediction for services and resources. 1) CSP configures the parameters of the capacity prediction system. 2) CSP maintains and configures parameters of AI algorithms and models. 3) CSP schedules cloud services or resources based on capacity prediction. 4) CSN provides capacity prediction analysis report to CSP.
Roles	CSN, CSP

Table I.8 – Use case: resource capacity prediction

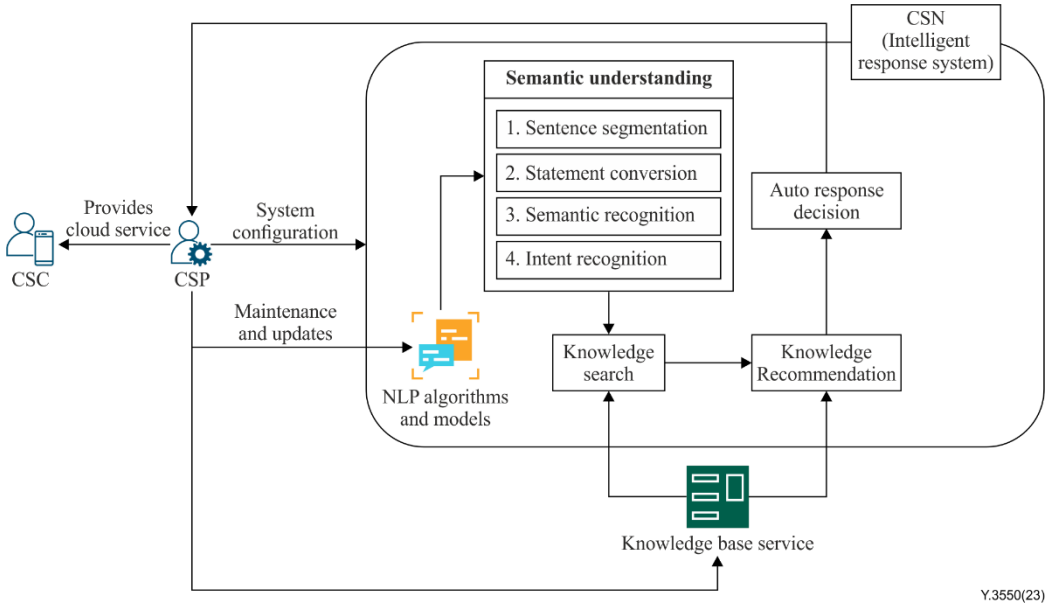
Figure (optional)	 **Figure I.8 – Resource capacity prediction**
Pre-conditions (optional)	CSP collects service resource usage data. CSN provides algorithm and modelling capability.
Post-conditions (optional)	
Derived requirements	– resource capacity prediction (refer to clause 7.10)

I.9 Use case: intelligent response

Table I.9 – Use case: intelligent response

Title	Intelligent response
Description	CSN provides an intelligent response system, including mechanisms like semantic understanding, knowledge search, knowledge recommendation, and automatic response, based on natural language processing (NLP) and intelligent robots to accurately understand CSC's questions and intentions, and organize responses in appropriate language to CSC. 1) CSC requests cloud service from the CSP. 2) CSP configures the parameters of the intelligent response system, and maintains and updates NLP algorithms, NLP models, and knowledge base. 3) CSP provides cloud service to CSC.
Roles	CSN, CSP, CSC

Table I.9 – Use case: intelligent response

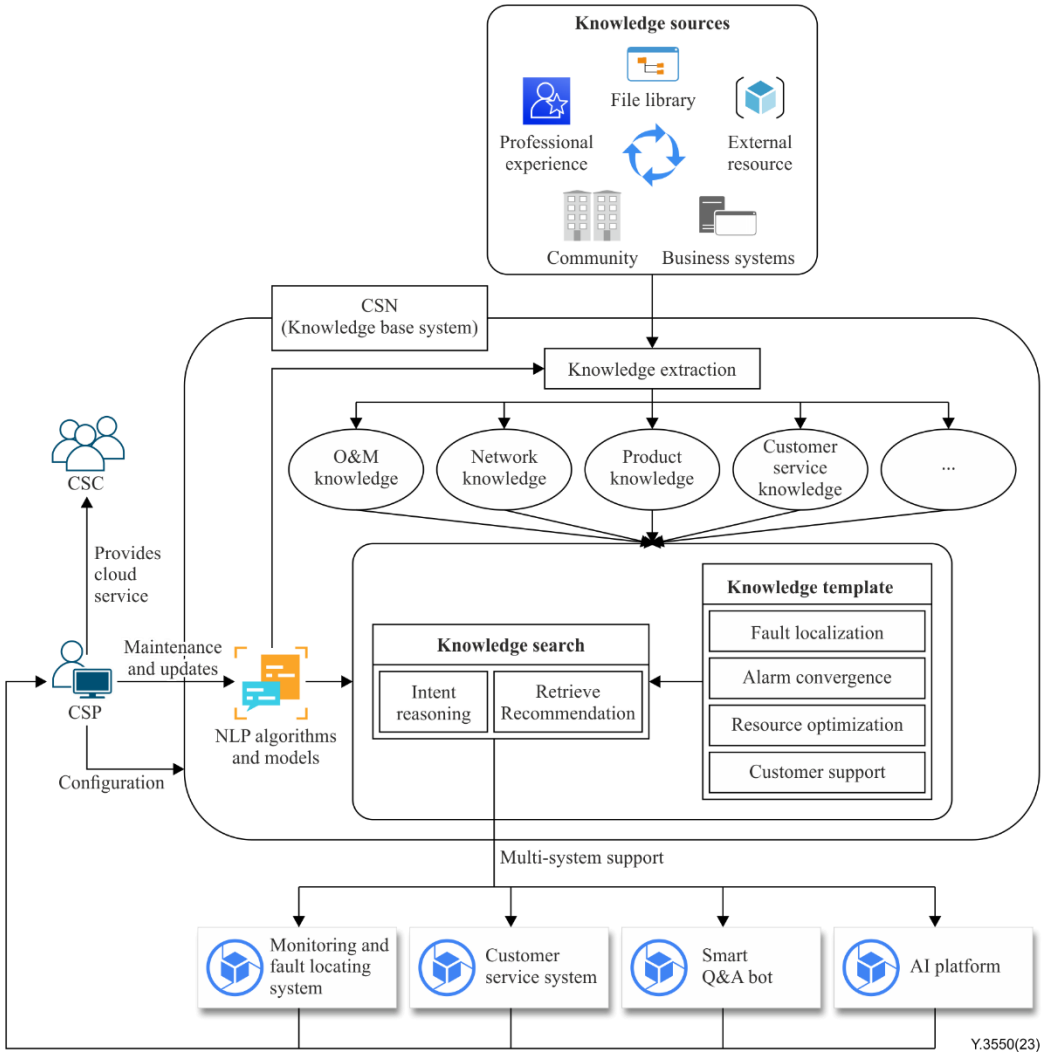
Figure (optional)	 **Figure I.9 – Intelligent response**
Pre-conditions (optional)	CSN provides NLP algorithms, and NLP models.
Post-conditions (optional)	
Derived requirements	– intelligent response (refer to clause 7.11)

I.10 Use case: knowledge base system management

Table I.10 – Use case: knowledge base system management

Title	Knowledge base system management
Description	CSN provides a knowledge base system, including the mechanism, knowledge extraction, knowledge templates and knowledge search, to analyse and identify different knowledge data with NLP algorithm and NLP models for knowledge extraction and template construction. It is used for template recommendation for several stages including fault location, alarm convergence, resource optimization, intelligence response, etc. 1) CSP maintains and updates the knowledge base system. 2) CSP provides cloud service to CSC based on a knowledge base system.
Roles	CSN, CSP, CSC

Table I.10 – Use case: knowledge base system management

Figure (optional)	 **Figure I.10 – Knowledge base system management**
Pre-conditions (optional)	CSP collects different knowledge data sources. CSN provides multi-system docking capability.
Post-conditions (optional)	
Derived requirements	– knowledge base management (refer to clause 7.12)

Bibliography

[b-ITU-T Y.3500] Recommendation ITU-T Y.3500 (2014) | ISO/IEC 17788:2014, *Information technology – Cloud computing – Overview and vocabulary*.

[b-ISO/IEC 2382] ISO/IEC 2382:2015, *Information technology – Vocabulary*. <https://www.iso.org/standard/63598.html>

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